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LETTER TO THE EDITOR

OBLIQUE INCIDENCE SPECULAR REFLECTIVITY OF UNIAXAL SEMICONDUCTORS NEAR TWO-DIMENSIONAL CRITICAL POINTS

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КОЭФФИЦИЕНТ ЗЕРКАЛЬНОГО ОТРАЖЕНИЯ ВБЛИЗИ ДВУМЕРНЫХ КРИТИЧЕСКИХ ТОЧЕК ПРИ НАКЛОННОМ ПАДЕНИИ СВЕТА НА ОДНООСНЫЕ ПОЛУПРОВОДНИКИ

The spectral dependence of specular reflectivity can help in detecting and identifying critical points. So far the cases of normal incidence [1, 2] and oblique incidence [3] reflectivity of isotropic semiconductors and the case of oblique incidence reflectivity of uniaxial semiconductors near three-dimensional critical points [4] have been considered.

Optically uniaxial crystals (composed of the trigonal, tetragonal and hexagonal systems) are characterized by $\hat{N}_\perp$ and $\hat{N}_\parallel$ (complex refractive indices for electromagnetic waves polarized so that the ***E*** vector vibrates normal to and parallel to the optic axis, respectively) or by the respective complex dielectric functions $\hat{\varepsilon}_\perp$ and $\hat{\varepsilon}_\parallel$. There holds

$$\hat{\varepsilon}_\perp = \varepsilon_{\perp 1} + i\varepsilon_{\perp 2} = \hat{N}_\perp^2 = (n_\perp + ik_\perp)^2, \tag{1}$$

$$\hat{\varepsilon}_\parallel = \varepsilon_{\parallel 1} + i\varepsilon_{\parallel 2} = \hat{N}_\parallel^2 = (n_\parallel + ik_\parallel)^2. \tag{2}$$

Components of each complex dielectric function (or of each complex refractive index) are related to one another by the Kramers-Kronig dispersion relations. The differences between $\varepsilon_{\perp 2}$ and $\varepsilon_{\parallel 2}$ arise from differences in the matrix elements governing the transitions. It was shown [4] that the spectral dependence of oblique incidence specular reflectivity for an extraordinary wave reflected by the plane normal to the optic axis (i.e. by the basal plane) can be used for the detection of the singularities of $\varepsilon_{\parallel 2}$, associated with the three-dimensional critical points when $\varepsilon_{\perp 2}$ is unsuitable to detect them.

We assume that the critical points are two-dimensional and the spectral dependence of $\varepsilon_{\perp 2}$ is unsuitable to detect them. For the direct transitions allowed in the electric dipole approximation we assume the matrix element for $\varepsilon_{\parallel 2}$ to be constant and different from zero and we neglect the weaker ω^{-2} factor [5]. Then the frequency dependences of the components of $\hat{\varepsilon}$ will have near the two-dimensional critical points a step function and logarithmic singularity characters [2] as shown in Fig. 1.

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In the case of reflection by the basal plane, the oblique incidence specular reflectivity of the uniaxial crystal for the extraordinary wave (i.e. $\boldsymbol{E}$ paralell to the plane of incidence) will be [6]

$$R_p = \frac{(a_\parallel - c\cos\varphi)^2 + (b_\parallel - d\cos\varphi)^2}{(a_\parallel + c\cos\varphi)^2 + (b_\parallel + d\cos\varphi)^2}, \tag{3}$$

where

$$2\begin{Bmatrix} a_\parallel^2 \\ b_\parallel^2 \end{Bmatrix} = [(n_\parallel^2 - k_\parallel^2 - \sin^2\varphi)^2 + 4n_\parallel^2 k_\parallel^2]^{1/2} \pm (n_\parallel^2 - k_\parallel^2 - \sin^2\varphi), \tag{4}$$

$$c = n_\parallel n_\perp - k_\parallel k_\perp, \tag{5}$$

$$d = n_\perp k_\parallel + n_\parallel k_\perp \tag{6}$$

and φ is the angle of incidence.

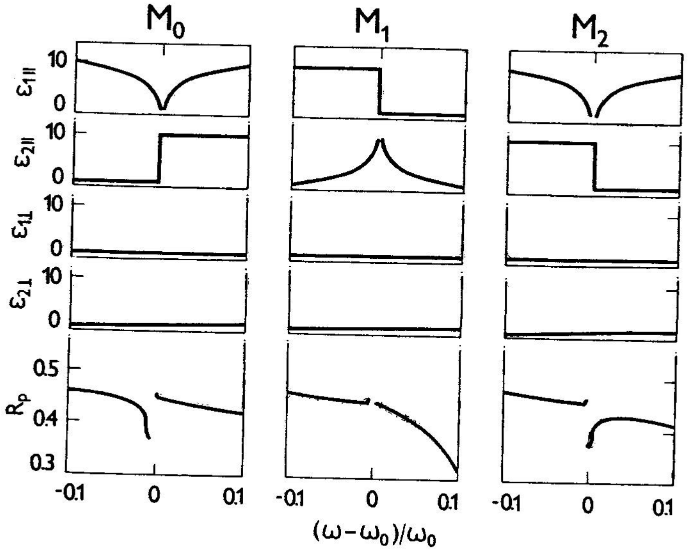

Fig. 1. Frequency dependences (near the two-dimensional critical points M_0, M_1, M_2) of the extraordinary wave oblique incidence specular reflectivity R_p, computed from the frequency dependences of real ε_1 and imaginary ε_2 components of the complex dielectric functions $\hat{\varepsilon}_\parallel$ and $\hat{\varepsilon}_\perp$. The angle of incidence $\varphi = 80°$. ω_0 is the frequency of the critical point.

Having assumed the above mentioned spectral dependence of the components of $\hat{\varepsilon}_\parallel$ and the nonsingular spectral dependence of the components of $\hat{\varepsilon}_\perp$, all shown in Fig. 1, and using the relations (1) to (6), we computed the spectral dependences of the extraordinary wave oblique incidence specular reflectivity R_p near two-dimensional critical points. Fig. 1 shows that the singularities of the components of $\hat{\varepsilon}_\parallel$ at critical points give rise to singularities of reflectivity R_p. So the spectral dependence of the extraordinary wave oblique incidence specular reflectivity at the basal plane reflection (at a large angle of incidence) can be used for the detection of the two-dimensional critical points of optically uniaxial crystals.

These critical points could be also detected by means of the spectral dependence of normal incidence specular reflectivity in the case of reflection by the plane parallel to the optic axis. But the production of such planar surface (normal to the easy-cleavage planes) often prevents to obtain the correct experimental results.

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